Macro-Models for Modeling and Simulation of Cooled Spindles

S. Züst[1], F. Pavliček[2], L. Fischer[3], L. Weiss[2], K. Wegener[1]

[1]Institute of machine tools and manufacturing (IWF), ETH Zürich, Switzerland

[2]inspire AG, Technoparkstrasse 1, 8005 Zürich, Switzerland

[3]CC Thermal Energy Systems & Process Engineering, HSLU, Switzerland

zuest@iwf.mavt.ethz.ch

Abstract

High precision turning and milling processes account for sophisticated spindle cooling strategies. This results from the thermal elongation of the spindle, as well as of the surrounding machine structures due non nominal and non-uniform temperature distributions caused by heat sources in the spindle [1]. These heat losses are caused in the electric drive and the bearings [2]. The geometric design of cooling ducts to extract this heat is a complex task due to the fluctuations in heat release and the temperature sensitivity of the coolants to heat input.

This approach presents a modeling and simulation approach to quantify the internal heat sources and estimate the heat transfer coefficients in the cooling duct to assist the geometric design of cooling ducts. The underlying model is divided into parametrizable macro-models allowing a time-efficient adaption to new spindles. To quantify the heat transfer between the coolant and the structure, the cooling duct is divided into a series of trivial geometric shapes, which can be characterized using the Nusselt correlations in [3]. By this step, time consuming CFD simulations are avoiding and time efficient iteration steps in the design are enabled. Comparison with empirical data and CFD simulations prove the validity of this approach.

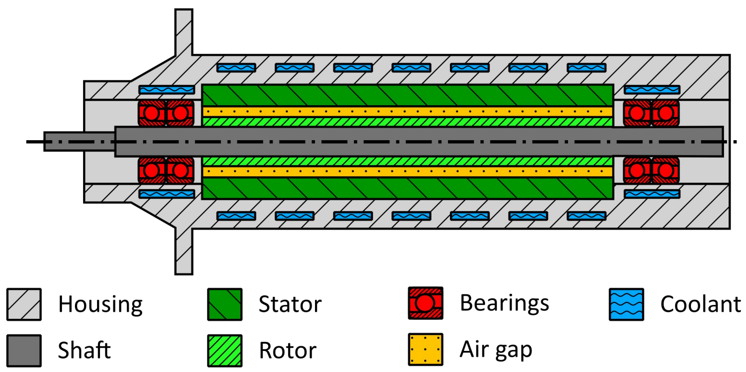

Figure 1: Generic representation of the modeled spindle with the implemented macro-models shown in different colours [4].

[1] J. Mayr, J. Jedrzejewski, E. Uhlmann, M. A. Donmez, W. Knapp, F. Härtig, K. Wendt, T. Moriwaki, R. Schmitt, P. Shore, C. Brecher, T. Würz, K. Wegener, 2012, Thermal Issues in Machine Tools, CIRP Annals - Manufacturing Technology, 61: 771–791.

[2] E. Abele, Y. Altintas, C. Brecher, 2010, Machine tool spindle units, CIRP Annals - Manufacturing Technology, 59: 781-802.

[3] P. Stephan, 2013, VDI-Wärmeatlas, 11. Auflage: VDI-Gesellschaft Verfahrenstechnik und Chemieingenieurwesen, Springer-Verlag Berlin Heidelberg.

[4] S. Züst, F. Pavliček, L. Fischer, L. Weiss, K. Wegener, 2016, Thermo-Energetic Modelling of Machine Tool Spindles with Active Cooling based on Macro Models, International Journal of Mechatronics and Manufacturing Systems, [in press].